

## mSTAR (mSTAR)

Completed Technology Project (2014 - 2014)



## Project Introduction

Mini-STAR (mSTAR) is a small satellite mission concept to test the hypothesis that the velocity of light is independent of the velocity and orientation of the reference frame. This element develops key enabling technology for the mission, in particular a fiber-coupled optical cavity and associated thermal enclosure, that provides the length reference necessary to implement a Kennedy-Thorndike experiment.

The Mini-STAR (mSTAR) mission concept has been developed to investigate a fundamental assumption of physics by searching for variations in the speed of light as a function of velocity of the reference frame. The discovery of such dependencies would revolutionize physics, change our understanding of how the Universe began and have profound implications for astrophysics, Special Relativity and the Standard Model that describes the physics of matter and energy.

Under this effort, Ames Research Center and Stanford University will explore the Mini-STAR program, an anticipated collaborative Saudi-German-US international effort to perform an advanced Kennedy-Thorndike (KT) test of Special Relativity using the large and rapid velocity modulation available in low Earth orbit (LEO). Using the experiences gained in the UV-LED program, this small satellite mission will have an expected improvement of about a factor of 100 over present ground results, with an additional factor of 10 possible using more advanced technology. To date, limits on Lorentz invariance violations (LIV) related to KT effects are on the order of  $\delta c/c \leq 10^{-15}$  while the KT coefficient limit is  $\leq 4 \times 10^{-8}$ . Space experiments in low Earth orbit offer a way to obtain much better results than ground experiments. The Mini-STAR KT experiment consists of the comparison of a molecular frequency reference, 532 nm Iodine, with a length reference (LR), ULE optical cavity, in a LEO flight (7 km/s orbital velocity). The corresponding sensitivity to a boost-dependent violation of Lorentz invariance, as modeled by the KT term in the Mansouri-Sexl test theory, would be  $\leq 7 \times 10^{-10}$ . The Mini-STAR approach is to develop a small-scale instrument with a high scientific output that also provides instrument and spacecraft technology for subsequent missions, which would use further improved frequency standards.

In this element, our approach is to develop key components of a compact instrument with a high scientific output that also provides instrument and spacecraft technology for subsequent smallsat missions exploring fundamental physics. The Mini-STAR approach will allow subsequent missions to take advantage of recent and expected improvements in frequency standards.

The Mini-STAR instrument consists of an Iodine clock and supporting Pound-Drever-Hall electronics (supplied by DLR); a fiber-coupled optical cavity inside a multi-layer passive/active thermal enclosure and cavity locking supporting electronics (based on a design by Stanford); a laser to supply light to the optical cavity; and an instrument electronics unit to collect instrument data



mSTAR

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## Organizational Responsibility

### Responsible Mission Directorate:

Mission Support Directorate (MSD)

### Lead Center / Facility:

Ames Research Center (ARC)

### Responsible Program:

Center Independent Research & Development: ARC IRAD

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and interface with the spacecraft. The Kennedy-Thorndike experiment compares the change in the frequency of the Iodine clock to the change in the length of the optical cavity as the spacecraft orbits the Earth.

The focus of the Ames/Stanford effort of this element is the development of the fiber-coupled optical cavity (length reference) and thermal enclosure. Stanford University currently has a 30,000 finesse cavity working in the lab that serves as the basis for the Mini-STAR design, which will require a cavity finesse of 100,000 or greater. In addition, Stanford has designed a four layer thermal isolation system that is expected to provide the  $10^9$  attenuation necessary to achieve nano-Kelvin level stability at the optical cavity.

This element will provide a substantial payoff to NASA by leveraging investments from foreign partners in the exploration of fundamental physics. Mini-STAR capabilities will provide new insights immediately and can be built upon to provide enhanced KT measurements in the future. Furthermore, the core technologies developed here, including the unprecedented thermal stability, will support new instruments beyond the cavity.

### Anticipated Benefits

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## Project Management

### Program Manager:

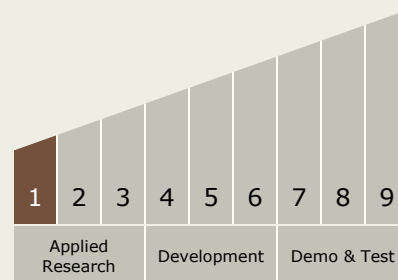
Harry Partridge

### Principal Investigator:

Chad R Frost

## Technology Maturity (TRL)

Start: 1



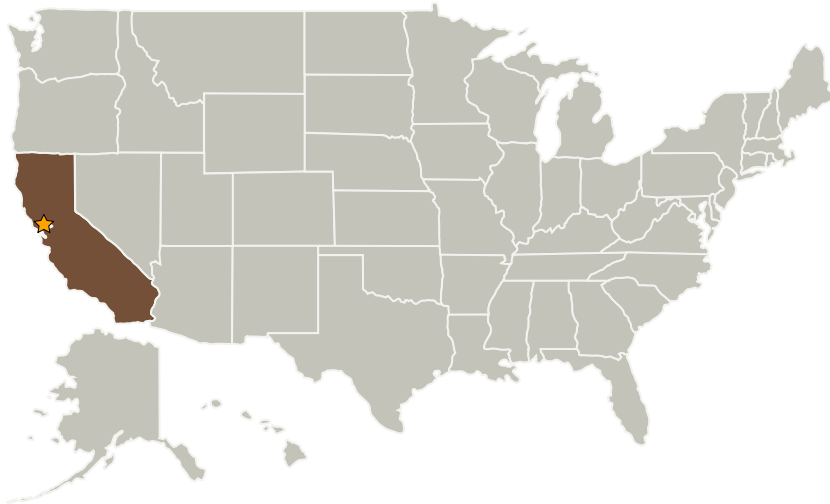
## Technology Areas

### Primary:

- TX08 Sensors and Instruments
  - └ TX08.1 Remote Sensing Instruments/Sensors
  - └ TX08.1.4 Microwave, Millimeter-, and Submillimeter-Waves



## Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
★Ames Research Center(ARC)	Lead Organization	NASA Center	Moffett Field, California

### Primary U.S. Work Locations

California

## Stories

1676 Approval #17536  
(<https://techport.nasa.gov/file/8767>)